ARKIV FÖR FYSIK Band 11 nr 36

Communicated 28 November 1956 by Bengt Edlén

Platinum *K* X-rays from radium sources

By Jan Cederlund

With 4 figures in the text

SUMMARY

The platinum *K* X-rays generated in the walls of a radium container were studied with a scintillation spectrometer. Special measures were adopted to reduce and correct for the strong Compton background due to the hard gamma-rays from radium.

A source, the rays of which simulated the hard beta rays from RaC, was used to estimate what a proportion of the observed peak was due to beta rays from RaC.

The number of photons in the *K* X-ray peak was found to be 0.030 per radium disintegration, or 1.4 per cent of the total number of photons emitted from the source.

Introduction

Radium sources are generally enclosed in platinum containers. Photons of energies not present in any member of the radium disintegration chain will be generated in the walls of the container, because of ionisation, bremsstrahlung and scatter.

Wyard [1] calculated the amount of bremsstrahlung and scatter from a radium source in a container with 0.5 mm platinum walls. It is very difficult to assess the energy distribution of this bremsstrahlung experimentally because of the strong gamma-

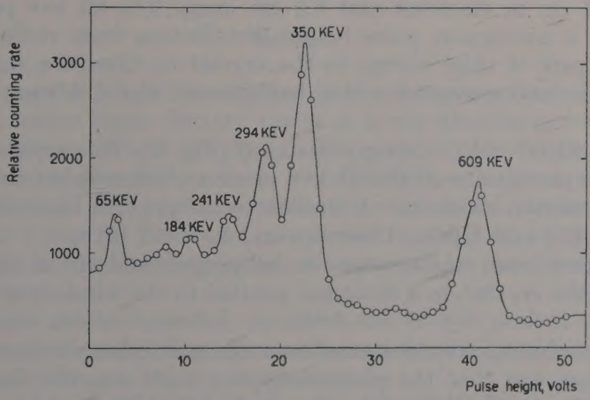

Fig. 1. Gamma-ray spectrum from a Ra source in a platinum container. The pulse height distribution was obtained with the aid of a Harshaw NaI (Tl) crystal (4.4 cm in diameter and 2.5 cm long) mounted on a Dumont 6292 photomultiplier. The peak at 65 kev includes the *K* X-radiation from Pt.

rays from radium itself. A scintillation spectrometer will, however, show a pronounced peak in the continuous energy distribution in the region of 65 kev.

The pulse height distribution of the gamma-rays from a radium source in a platinum container is given in Fig. 1, from which it is also apparent that the peak at 65 kev, which represents the K X-radiation from Pt, is comparable in intensity to some of the gamma-ray peaks. The purpose of the present investigation was to determine the number of photons in this peak for a special radium source, consisting of 4.35 mg radium-sulphate in the form of a cylinder 1.7 mm diameter and 1.7 mm long, enclosed in a container with 0.5 mm platinum walls.

Production of 65 kev X-radiation

The 65 kev peak can be explained by the following three processes.

1. Most of the photo-electrically absorbed gamma-ray photons give rise to platinum K X-radiation.

2. Many of the beta-particles ionize platinum atoms in their K-shell. Most of these atoms return to the ground state by emission of K X-ray photons. These photons with energy immediately below the K-absorption edge have a fair chance of passing through the walls of the container.

3. The part of the continuous bremsstrahlung produced immediately below the K-absorption edge, is relatively little absorbed in the walls of the container. The resolving power of the scintillation spectrometer is not high enough to distinguish these photons from proper K X-radiation.

Of these effects, No. 1 can be estimated if the geometry of the container, and the decay schemes of the members of the radium disintegration chain is known, while Nos. 2 and 3 are not readily estimated theoretically.

Instrumentation and method

The pulse height distribution given in Fig. 1 was obtained with the aid of a fairly large crystal (4.4 cm in diameter and 2.5 cm long). The 65 kev peak is therefore superimposed on a continuous pulse height distribution from radium gamma-rays, which have lost part of their energy in the crystal by Compton interaction. In an attempt to reduce and correct for this background the following three measures were adopted.

1. A thin crystal (15 × 15 × 5 mm) was used (Fig. 2). This crystal was still thick enough to absorb practically all the 65 kev photons, but reduced the background of pulses due to Compton electrons. A similar technique has been employed by Leboeuf and Stark [2], and Upson, Connally and Leboeuf [3].

2. The collimated beam was arranged to fall perpendicularly on one of the 15 × 15 mm surfaces of the crystal, in a direction parallel to the window of the photomultiplier (Fig. 2).

Thus no gamma photons were scattered from the multiplier window into the crystal. Another advantage was that the photomultiplier itself was not irradiated.

3. A tin filter (1 mm thick) could when desired be introduced in the path of the beam. This filter absorbed almost all the 65 kev photons, but on the average only 10 per cent of the gamma-rays. In this way the K X-radiation could be separated from the background.

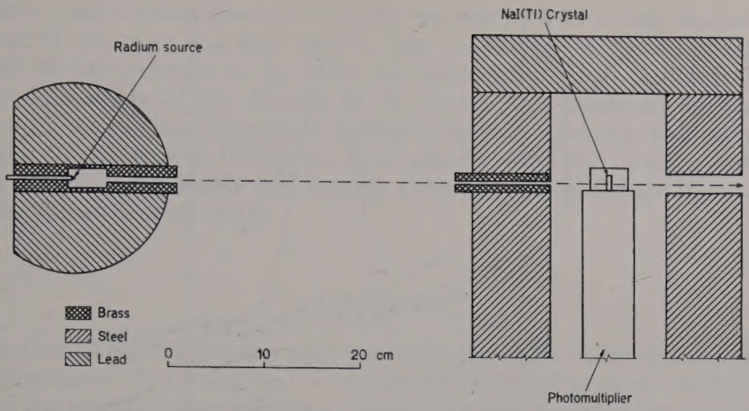

Fig. 2. Radium source, with shielding, collimator and detector part of scintillation spectrometer.

Fig. 2 shows the source, shielding, collimator, and detector part of the spectrometer. In order to avoid production of *K* X-radiation in the energy region of interest the collimator was made of brass. Most gamma-ray photons passed through the crystal without interaction. If they had been allowed to fall on the walls of the detector shielding, many of them might have been scattered back into the crystal. The cylindric steel shield was therefore provided with an exit aperture.

In order to estimate the number of 65 kev photons due to the hard beta radiation from RaC a source was prepared, which simulated this beta radiation. This source consisted of 0.67 mc Ce^{144}–Pr^{144}, homogeneously mixed with $BaCl_2$, in a platinum container of the same dimensions as that containing the radium.

The radiation from Ce^{144} itself has beta-rays of maximum energy of 0.30 and 0.17 Mev, and only weak gamma-rays of energy greater than 0.134 Mev. The radiation of interest in this connection is the 2.97 Mev beta-rays from the short-lived daughter product Pr^{144}.

Results

Fig. 3 shows the pulse height distribution in the energy region 0–100 kev from the radium-platinum source (open circles). Curve *A* is the distribution with no tin filter inserted between the source and the crystal. The peak at pulse-height 16 volts corresponds to the 65 kev *K* X-radiation from Pt, while the small peak at 7 volts corresponds to the iodine *K* X-ray escape peak. Curve *B* (solid circles) represents the distribution when 1 mm Sn filter was introduced in the path of the beam.

Curve *C* (dashed line) is the distribution *B* corrected for the absorption of gamma photons in the filter.

Thus *C* represents the background, on which the 65 kev peak is superimposed. It was calculated from *A* and *C* that the number of 65 kev photons emitted per Ra disintegration was 0.030.

Fig. 4 shows the pulse height distribution from the Ce^{144}–Pr^{144} source. The 134 kev peak at 32 volts is the only gamma-ray peak of any importance, and is readily corrected for. From the peak at 16 volts together with the iodine X-ray excape peak at 7 volts one can calculate the number of 65 kev photons produced per Pr^{144} disintegra-

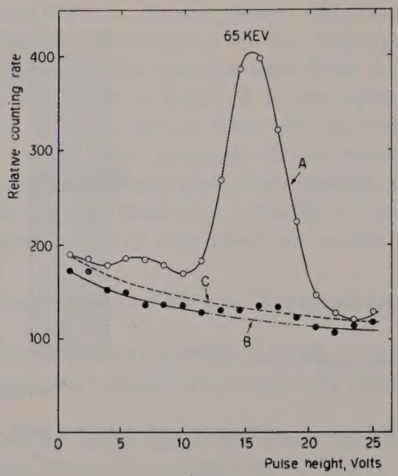

Fig. 3. Pulse height distribution in the energy region 0–100 kev from the radium platinum source. Curve *A* (open circles) is the distribution without filter between the source and the crystal. The peak at pulse height 16 volts corresponds to the 65 kev *K* X-radiation from Pt, while the small peak at 7 volts corresponds to the iodine *K* X-ray escape peak. Curve *B* (solid circles) represents the distribution when a 1 mm tin filter is introduced into the path of the beam. Curve *C* (dashed line) is the distribution *B* corrected for the absorption of gamma photons in the filter.

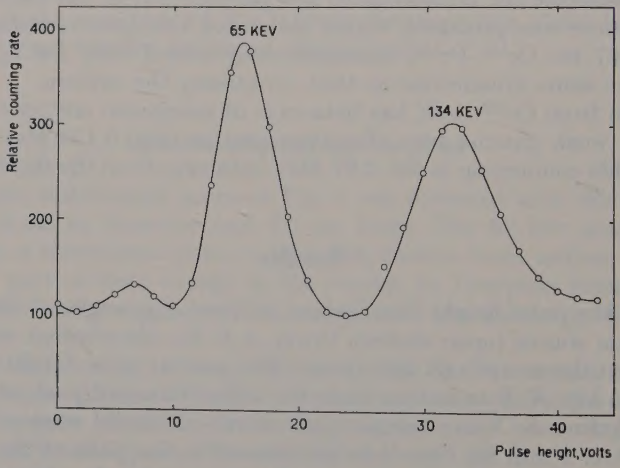

Fig. 4. Pulse height distribution from a Ce ^{144}–Pr^{144} source in a platinum container. The peak at 65 kevis due to bremsstrahlung and *K* X-radiation from platinum. The 134 kev peak is due to a gamma ray from the decay of Ce^{144}.

tion. The beta spectra of Pr^{144} and RaC have maximum energies of 2.97 and 3.17 Mev, respectively, and both have allowed shape (Kageyama [4], Emmerich [5]). From a recent investigation (Starfelt, Cederlund and Lidén [6]) one can estimate that RaC produces 5 per cent more 65 kev photons per beta disintegration than Pr^{144}.

Taking into consideration that Pr^{144} decays by the 2.97 Mev beta disintegration in 97 per cent of the cases and RaC by 3.17 Mev in 23 per cent, one can estimate the number of 65 kev photons to be 0.008 per disintegration of Ra. Using the decay scheme of Johansson [7] the number of 65 kev photons produced by photoelectric absorption of the gamma-photons is estimated to 0.015 per Ra disintegration. The remaining 0.007 photons in the 65 kev peak are probably due to the other beta-rays in the Ra disintegration chain, and to some extent to *K* X-radiation from some members in the disintegration chain.

Conclusion

Compared with the 2.2 gamma photons emitted per Ra disintegration, the 65 kev photons correspond to 1.4 per cent of the total number of photons emitted from the source and are readily observed with a gamma-ray spectrometer. On account of their low energy, however, their contribution to the total dose rate, measured in rad units, is only 0.18 per cent.

I wish to express my thanks to Dr. K. Lidén for suggesting the problem and for valuable criticism and support.

Radiation Physics Department, University of Lund, Sweden.

REFERENCES

1. S. J. Wyard, Nucleonics *13*, No. 7, July 1955.
2. M. B. Leboeuf and B. T. Stark, H. W.-31961, Hanford Atomic Products Operation Richland, Washington, May 27, 1954.
3. U. L. Upson, R. E. Connally, and M. B. Leboeuf, Nucleonics *13*, No. 4, April 1955.
4. S. Kageyama, J. Phys. Soc. Jap. *8*, 689 (1953).
5. W. S. Emmerich, W. J. Auth, and J. D. Kurbatov, Phys. Rev. *94*, 111 (1954).
6. N. Starfelt, J. Cederlund, and K. Lidén, to be published.
7. S. A. E. Johansson, Arkiv för Fysik *9*, 561 (1955).

Tryckt den 2 februari 1957

Uppsala 1957. Almqvist & Wiksells Boktryckeri AB